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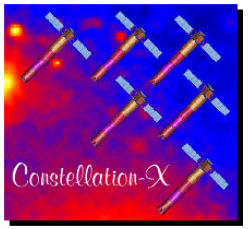

Mission Architecture Study
FST Presentation

September 24, 1998

Goddard Space Flight Center

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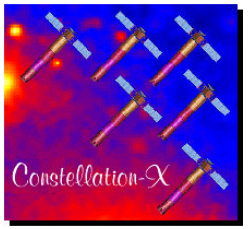
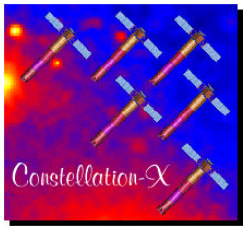
Study Contributors



- Mark Skinner - Study Manager
- Jeremy Stober - Mission Architecture
- Chris Miller - Cryogenics
- Rich Reinert - Spacecraft, VESAT Study
- Rich Reinker - Cryogenics
- Greg Fickbohm - Cost Analyst
- Bob Poley - Thermal Analyst
- Arne Erikson - Structural Analyst
- Steve Jordan - Engineering Management Rep.
- Terry Schrepel - Launch Vehicles
- Randy Rose - ASPEN Advanced S/c Arch. IRAD
- Paul Lightsey - NGST Mission Arch. Study
- Bill Kiehl - Technology Roadmap
- Bill Deininger - Technical Review
- Shanna Cox - Administrative

Study Overview - Objectives



- Create one or more mission concepts that meet overall requirements
- Identify unproven technologies, and create roadmaps
- Minimize end-to-end mission costs
- Create ROM schedules & costs for mission elements
- Scope of study excludes optics, detectors, and science operations

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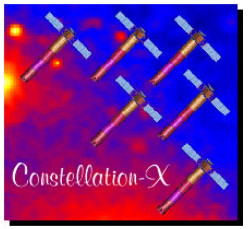
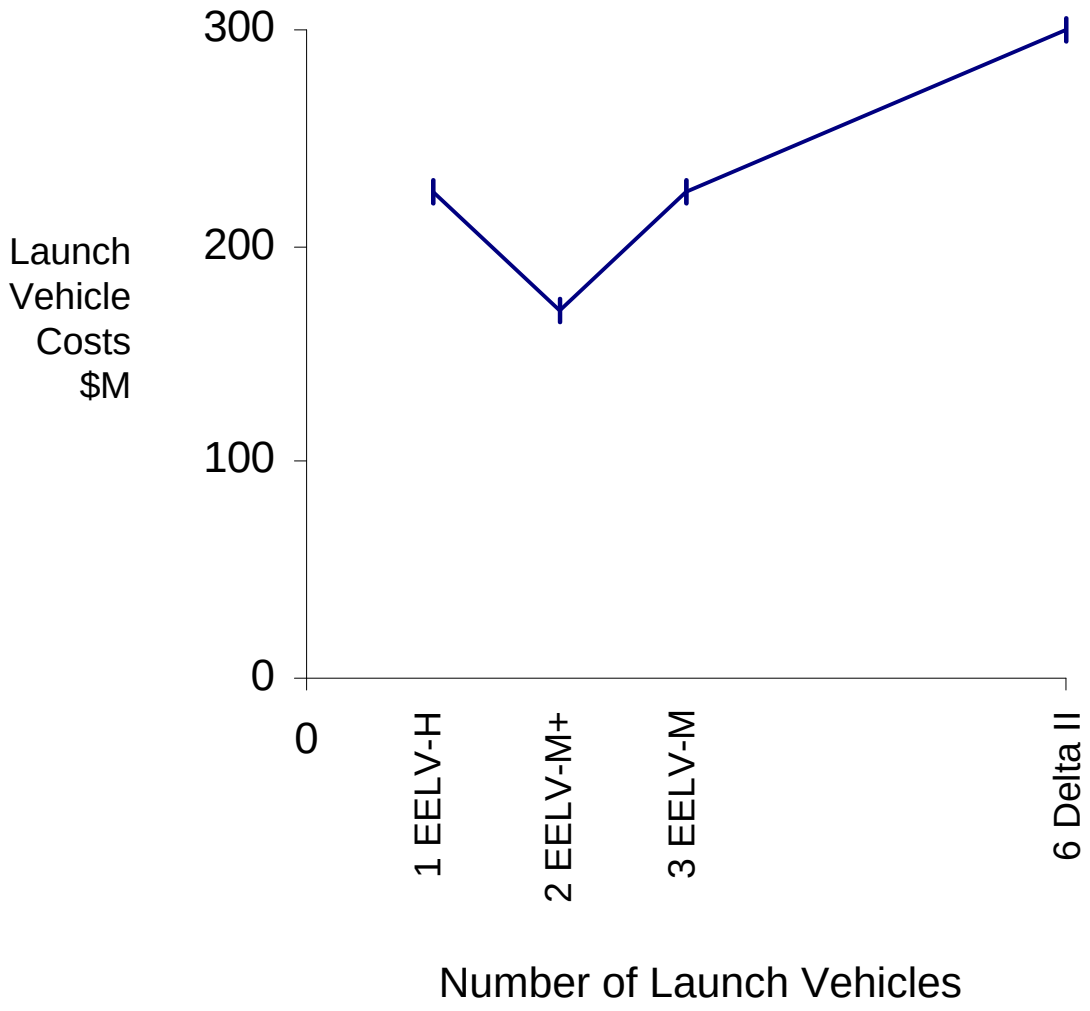
Using 2 Launch Vehicles Saves $$$ Versus Any Other Launch Option





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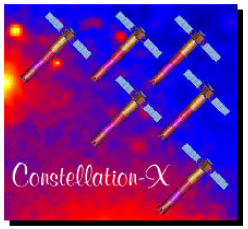
Launch Vehicles
Near Performance Range



	Candidate Vehicle	Provider	Country of Origin	Status	P/L to GTO (kg)	P/L to L2	Shroud Cylindrical section,, L x Dia, m
A) Domestic Launch Vehicles:							
1	Atlas II ARS	Boeing/ILS	USA	Development	4500	3170	4.2 x 2.7
2	Delta IV Medium +	Boeing	USA	Development	4500	3170 (est.)	10 x 4.6
3	Delta IV M+ w/Solids	Boeing	USA	Development	8000	5600 (est.)	10 x 4.6
4	Titan/Centaur SRMU	LMA	USA	Operational	N/A	8600	12 x 5
B) Foreign Launch Vehicles							
1	GSLV Mk3	Antrix	India	Development	3500	2500 (est.)	TBD
2	CZ-3B	CGWIC	China	Operational	4850	3400 (est.)	TBD
3	Zenit 3 SL	Boeing/Sealaunch	International	Development	5000	3500	TBD
4	H2A 212	NASDA/RSC	Japan	Development	5000	3500 (est.)	4.6 x 4.6
5	Ariane 5	Arianespace	Europe	Operational	5600	4100	10 x 4.6
6	Proton	Krunichev/ILS	Russia	Operational	N/A	4800	3.5 x 3.8
7	Ariane 5E	Arianespace	Europe	Development	8000	5600 (est.)	10 x 4.6

Notes:

1) Where applicable, P/L to L2 estimated using ratio of GTO to L2 throw weight shown for Atlas II ARS (70%)

2) Candidate Vehicles selected from table "Launchers of the World" in International Space Industries Report dated 6/6/98

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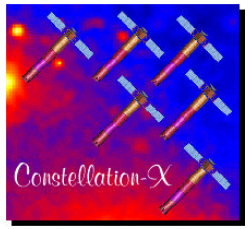
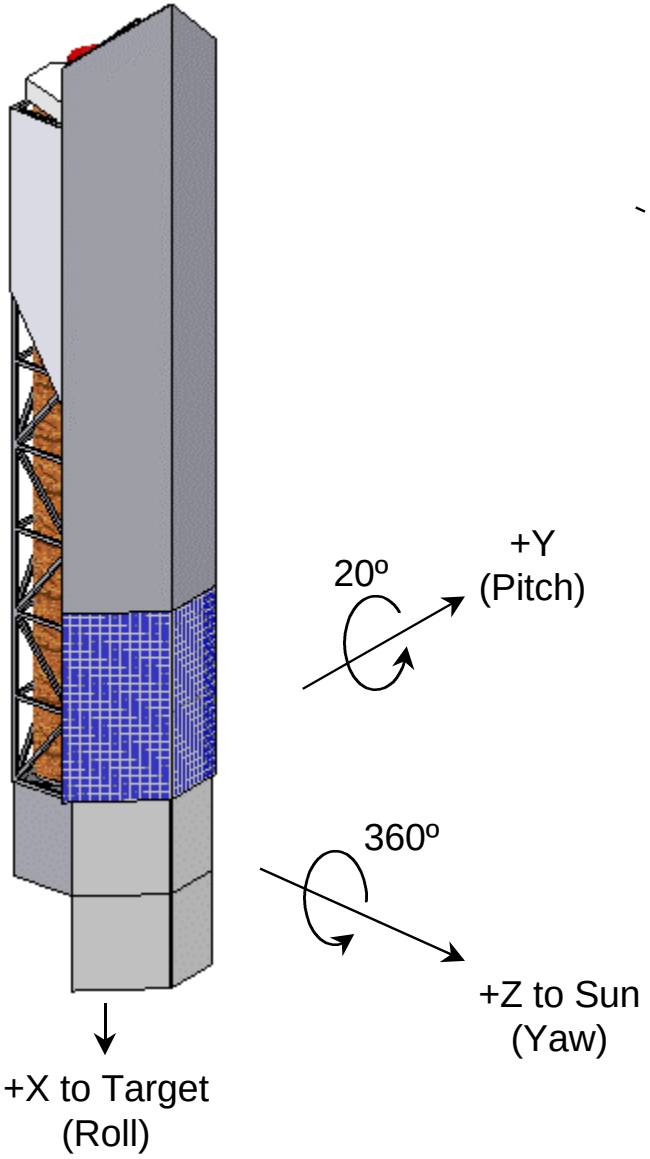
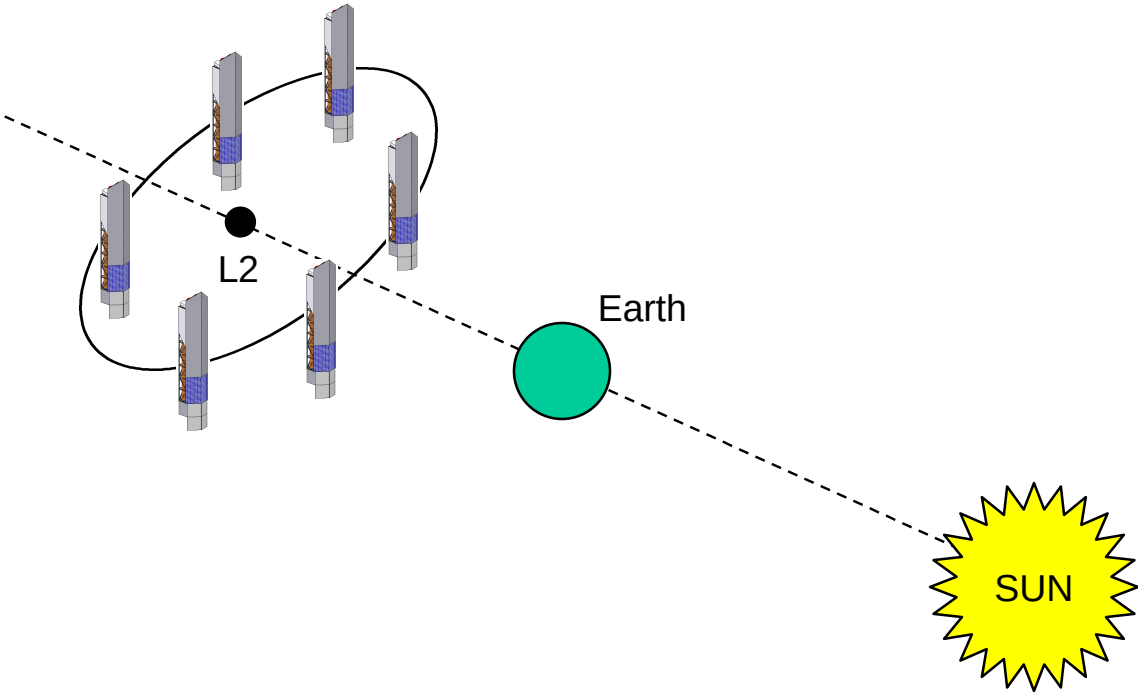
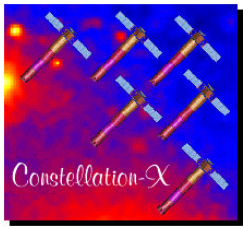
Modified "Starting Point" Mission Concept







"Starting Point" Mission Concept Modified and Studied in Detail



- Six spacecraft to L2 launched on two EELV-M+ launch vehicles
- One 1.3 m SXTs & Three 0.28 m HXTs per spacecraft
- Fixed optical bench - deployable dust covers and light shade
- Observatory points 90°, ±20°, to sunline
- Fixed sunshade & solar panels permit dewar cooling to ~ 60 K
- X-band communications via dedicated 10 m ground antenna
  - ~6 hours per day total at 1 Mbps
- "Unlimited" lifetime mechanical cryocooler & Advanced ADR
  - Requires technology development
- Use existing x-ray science data center & infrastructure

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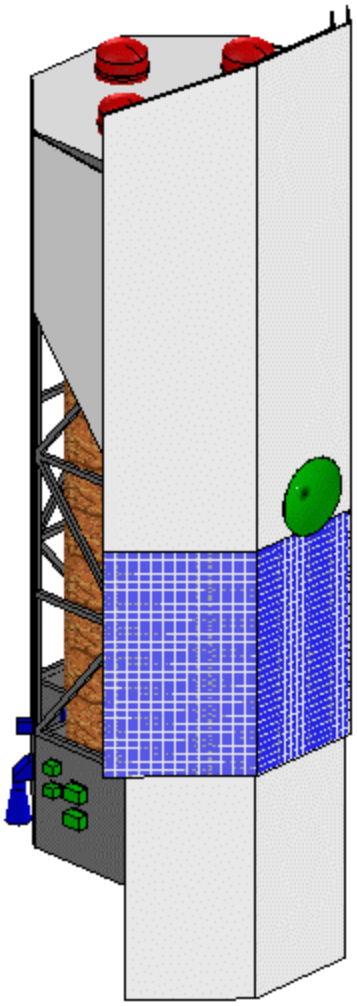
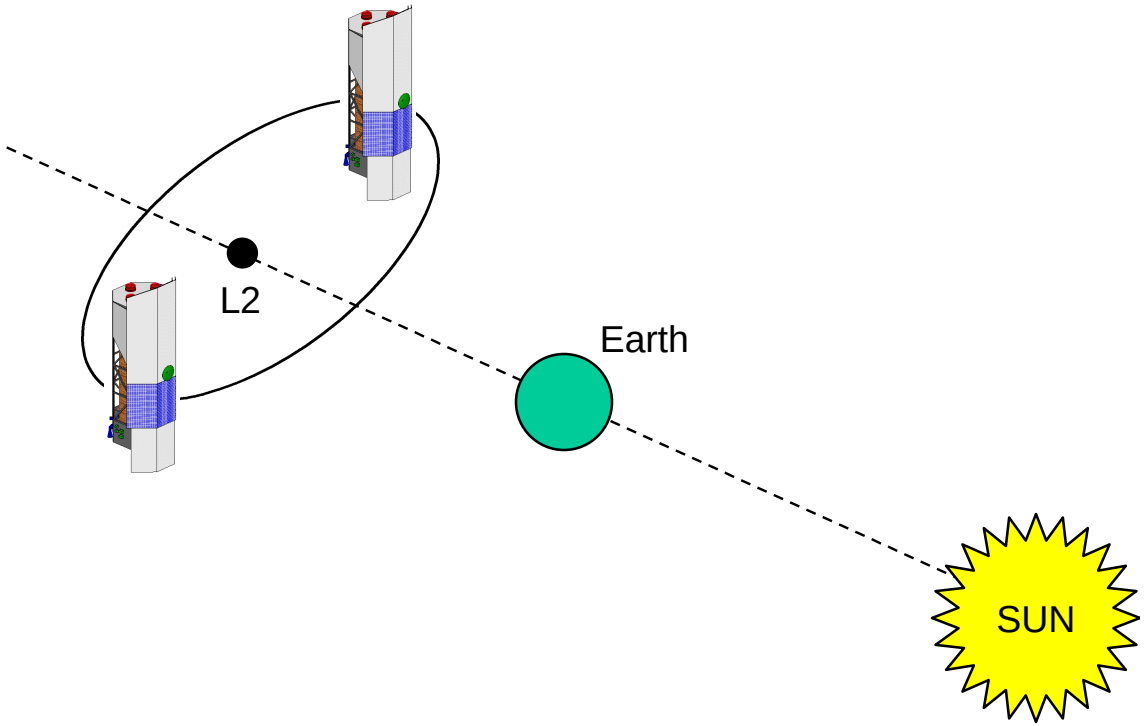
Evolved Mission Concept



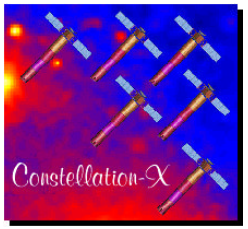


20º
+Y
(Pitch)

360º
+Z to Sun
(Yaw)

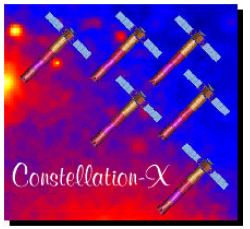
+X to Target
(Roll)

Evolved Mission Concept



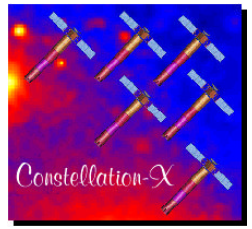
- Two spacecraft to L2 launched on two EELV-M+ launch vehicles
- Three 1.3 m SXTs & nine 0.28 m HXTs per spacecraft
- Fixed optical bench - deployable dust covers and light shade
- Observatory points 90°, ±20°, to sunline
- Fixed sunshade & solar panels permit dewar cooling to ~ 60 K
- X-band communications via dedicated 10 m ground antenna
  - ~6 hours per day total at 1 Mbps
- “Unlimited” lifetime mechanical cryocooler & Advanced ADR
  - Requires technology development
- Use existing x-ray science data center & infrastructure

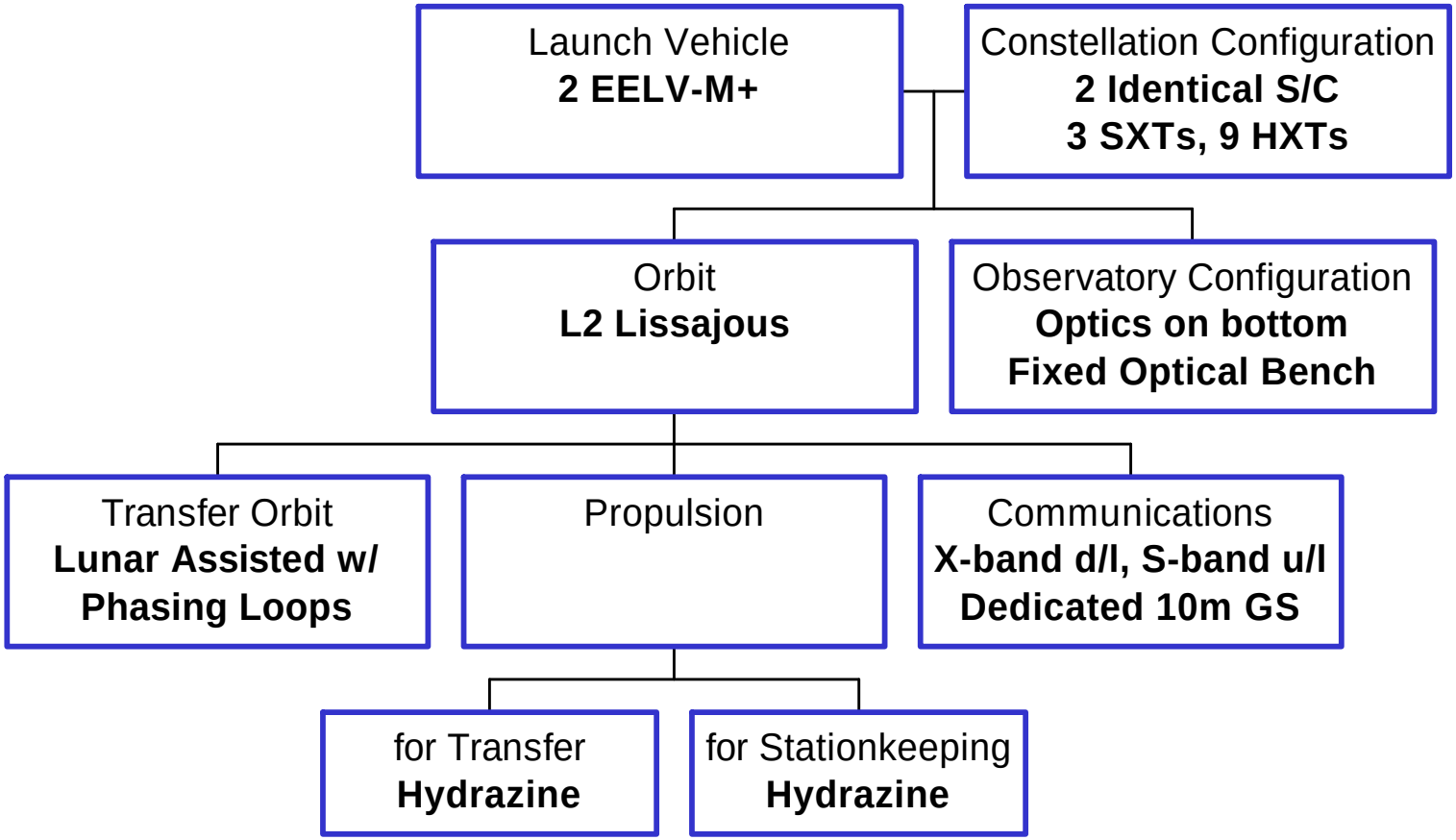
Key Technologies



- EELV-M launch vehicle
  - USAF Procurement; 1st launch 2001 (34 ILS launches ‘02-’05)
  - Large commercial market almost assures development
- Advanced Adiabatic Demagnetization Refrigerator (ADR)
  - Laboratory prototypes at SAO & NIST-boulder
  - Need development of flight model
- Cold operating cryocooler
  - Room temperature exists
- Large low-temperature, low-conductivity composite structure engineering model
  - Coupon, stress, etc., Testing at predicted temperatures
  - Trade between GFRC and gamma-alumina

Trade Summary





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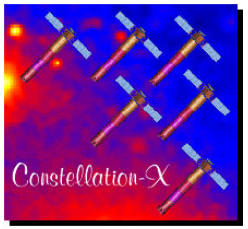
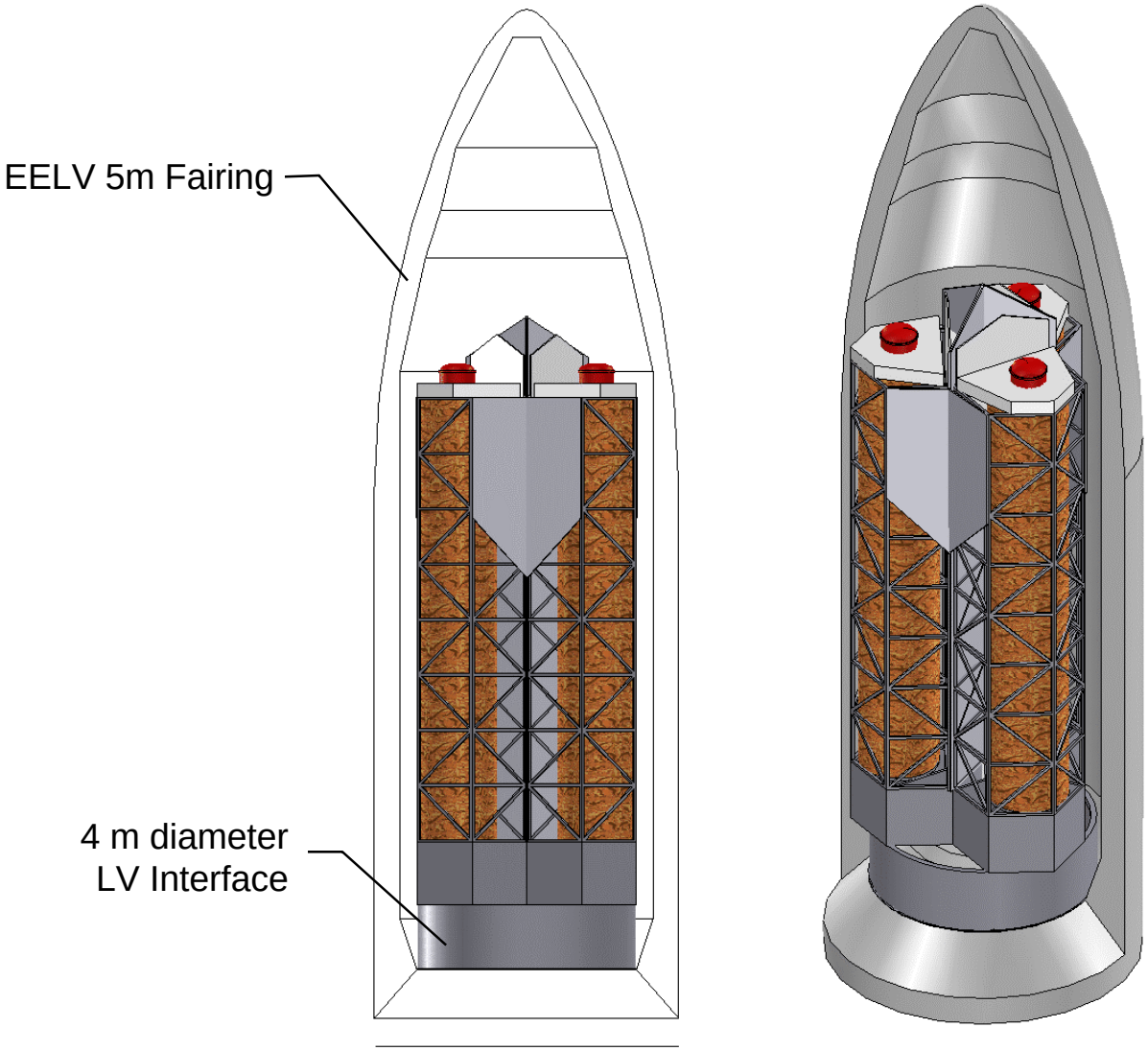
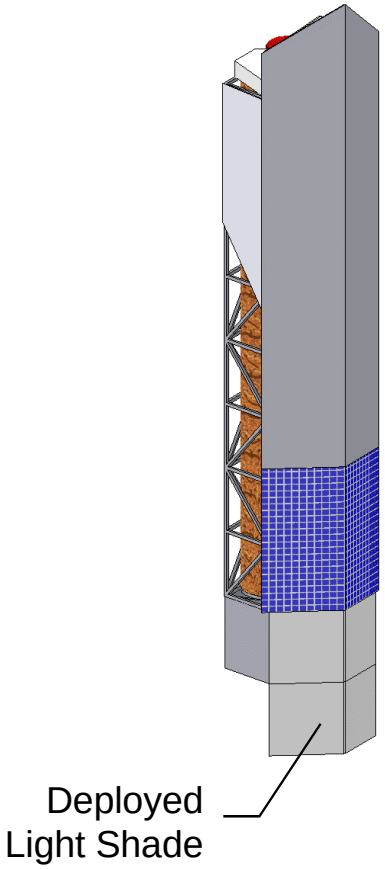
Ball's Modified "Starting Point" Mission Concept







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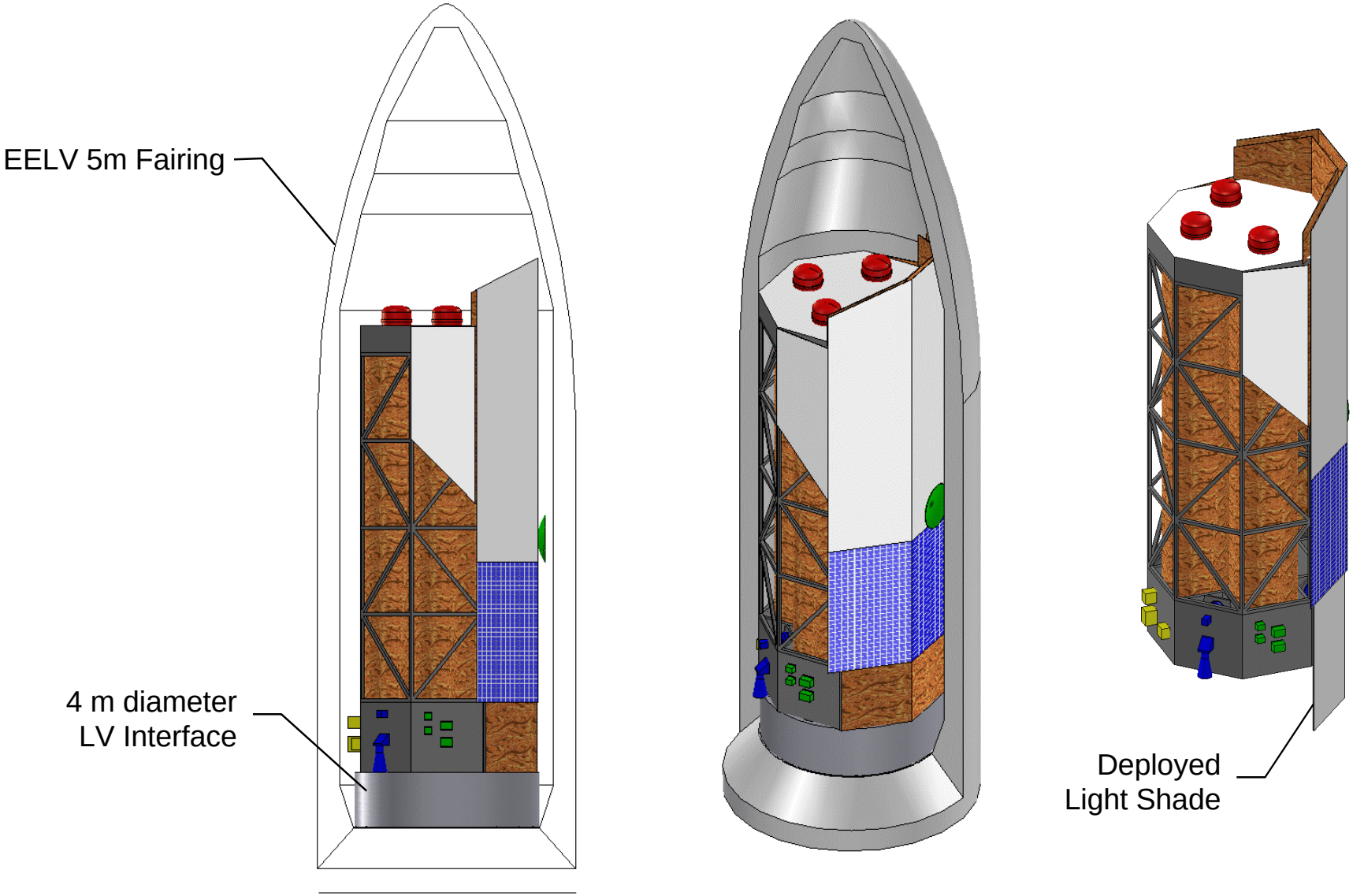
Ball's Evolved Mission Concept Fits in the EELV 5m Fairing With a Fixed Optical Bench



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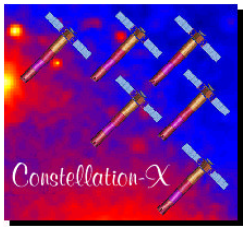
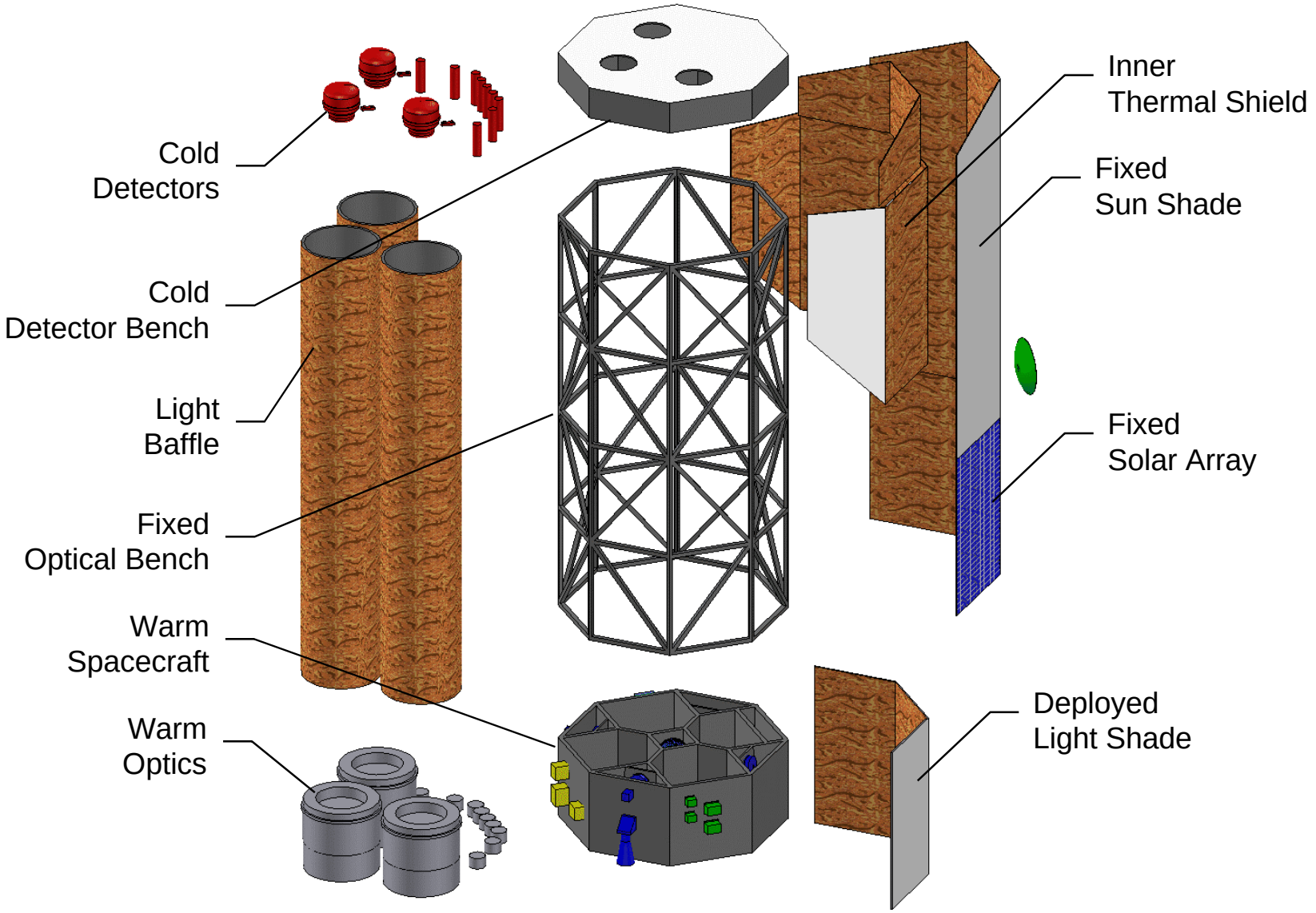
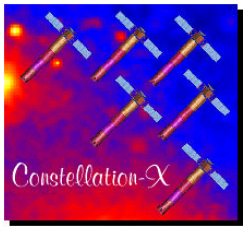
Ball's Evolved Mission Concept Has Cold Detectors Away From Warm Optics and Bus





Three Temperature Stages are Provided

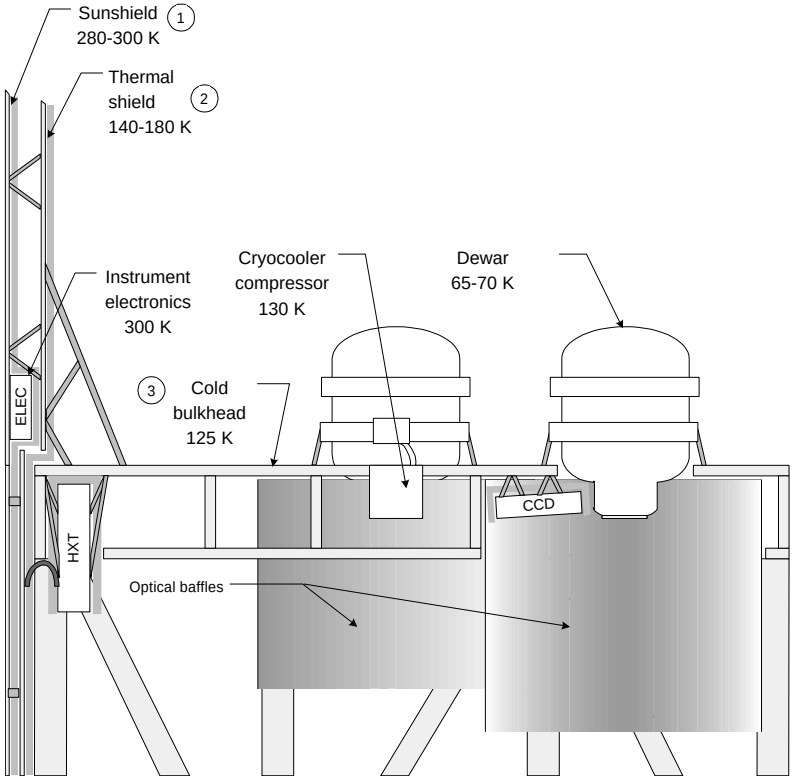


- Thermal design provides three temperature stages

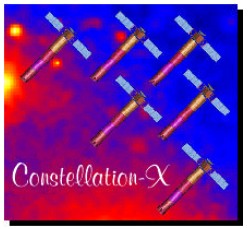
① Sunshield: 280-300 K
  - Thermal sink for detector electronics; within 2.5 m of all instruments

② Thermal shield: 140-180 K
  - Thermal sink for HXTs (233 K)

③ Cold bulkhead: 125 K
  - Mechanical interface for all instruments
  - Thermal sink for cryocoolers and CCDs (183 K)



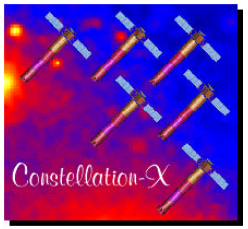
Performance for Three Candidate Cryogenic Systems



	Description	Lifetime	Components	Mass	Power	Technology Status
Reference Concept	4 to 6 K mechanical cryocooler; advanced ADR	10+ years	Cryocooler + dewar + ADR	90 kg	~50 W + ADR	• Two 4-10 K coolers now in development[1,2] • Advanced 4 K ADR demonstrated in lab[3]
Option 2	65 liters SfHe guarded with 10 K mechanical cryo-cooler; traditional ADR	5 years	Cryocooler + dewar + SfHe + ADR	110 kg	~27 W + ADR	• Two 4-10 K coolers now in development[1,2]
Option 3	65 liters SfHe guarded with 85 liters solid hydrogen at 10 K; traditional ADR	5 years	Dewar + SfHe + SH2 + ADR	130 kg	ADR only	• Fully developed[4]

1 Creare 4-10 K turbo-Brayton cooler, funded by GSFC & Air Force Research Laboratory
2 Ball 10 K Stirling/J-T Cryocooler, funded by Air Force Research Laboratory
3 Two-pill design at NIST-Boulder, two-stage design at SAO
4 ADR technology demonstrated on XRS ASTRO-E, cryogenics technology on numerous programs

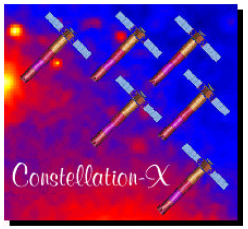
Technology Development Schedule



- Recommended technology development schedule fits a Constellation-X start in 2003

	1998	1999	2000	2001	2002
Creare 4-10 K turbo-Brayton cryocooler					
Ball 10 K Stirling/J-T cryocooler					
Stirling low-temp regenerator development					
Heat switch development					
High-Tc superconducting leads					
Two-stage/two pill ADR prototype					
Development tasks already in progress					
Development tasks recommended for Con-X					

Next Step



- Detailed risk assessment
- Better cost estimation
  - bring in major sub-contractors as team members
  - get quotes on mission-specific hardware
  - more detailed schedule
  - more grass-roots estimation based on this schedule
  - detailed, independent review of all sub-systems
  - some modeling, for sanity check
- Cryogenics Technology Roadmap Items
- Engineering models
  - How high fidelity?
  - Mission Strategy
- Further structural design
  - lower mass, higher stiffness
- Continue monitoring of launch vehicle situation
- Better modeling of observatory
  - Structural, Thermal, ADCS
- Consider need for a focus mechanism
- Examine spacecraft charging issue
- Stray light analysis